International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.9, pp 937-948, 2017

Experimental Investigation on Lubricating Oil by Using Bio-Diesel as Fuel in Ci Engine

Ajmal Roshan P.V.[1]*, S.sivakumar[2]

Department of Mechanical Engineering, RVS College of Engineering and Technology, Coimbatore 641402, India

Abstract : Biodiesel is an alternative fuel that can be produced from renewable feedstock such as edible and not- edible, vegetable oils and animal fats. Various properties of bio-diesel and diesel fuel are found to be comparable according to the past research. The increased use of biodiesel fuels has raised concerns over the impact of the fuel on the engine performance. In searching of the new source, cardanol has been selected as the alternative fuel. A four stroke diesel compression-ignition (CI)engine was subjected to run in on- road tests, fuelled by optimized biodiesel blend (40% cardanol oil) and diesel oil respectively Various tribological studies on lubricating oil samples, drawn in the service the interval for the single cylinder engine was conducted, in order to correlate the comparative performance of the two fuels (diesel and B40%) and the effectof fuel on lubricating oil performance. A number of tests were conducted in order to evaluate comparative performance of the fuels such as density, viscosity, flash point, ash content, moisture content, Total base number(TBN), Total Acid number(TAN), acid value and volatile matter determination, etc.Wear properties of lubricants are presently determined by the pin on disc wear tests. All these tests were. are carried out as per the ASTM methods. Performance of B40 is found to be superior to that of diesel fuel and the lubricating oil life is found to have increased while operating the engine on this fuel and the operating cycle can be increased.
Key words : Bio diesel,lubricating oil, properties.

1 Introduction

Biodiesel is the most readily considered alternative to mineral diesel at the current stage of technology development, which remains the most widely used transportation fuel. The recent research and development studies show that biodiesel demonstration programs have focused on the markets that have the greatest chance of choosing biodiesel despite its higher cost. These markets place a premium on biodegradability, non-toxicity, lower emissions profile, and overall environmental benefits of biodiesel. Neat biodiesel is as biodegradable as sugar and less toxic than salt. A research study at the University of Idaho shows that neat biodiesel degraded up to four times faster than petroleum diesel, and a blend (50% petroleum diesel and 50% biodiesel) biodegraded in one-third the time required by petroleum-based diesel fuel[1].Large-scale implementation of biodiesel, its effects on engine performance, emissions, durability, and lubricating oil degradation need to be investigated. Biodiesel is differently blended with standard diesel the formation of B40 (40% bio fuel and 60% standard diesel). The pure form of Biodiesel (B100) is cannot be used in the standard diesel engine; it requires some modifications like injection timing and pressure, change in valve angle, etc.

Investigation on the effects of any new alternative fuel on tribological properties of the lubricating oil is veryimportant for assessing the suitability of new fuel for existing engines various lubricating oil investigations were carried out to get an assessment about the health of lubricating oil and the engine. All these tests were used for indirect interpretation of comparative performance of new fuels in unmodified engines

Some studies have experimentally evaluated the lubricating oil degradation during long duration tests on static engines experiments and field trials,For more than 50% concentration of rapeseed oil methyl ester (RME) in the fuel, the slight reduction in lubricating oil viscosity with usage was observed but it was not significant enough to alter the lubricating oil change interval [1].Verhaeven investigated the effect of RME and used vegetable oil methyl ester on engine durability in a demonstration study using ten vehicles operated over a varying thousands of kilometers [2].Analysis of the lubricating oil samples taken at different interval, vehicle run confirmed that no special degradation of the engine or lubricating oil took place [2]. Lin et al. compared the effect of fuels on lubricating oil degradation over hundreds of hours operation of heavy duty diesel engine fuelled with palm biodiesel blends [3].They reported that viscosity (@ 40 ^{0}C) of the lubricating oil for the diesel fuelled engine after several hours reduced to 95.1 cSt from the initial viscosity of 107 cSt. Staat and Gateau reported the results of 3 years long investigations on 2000 vehicles in France using RME as fuel [4]For more than 50% concentration of RMEin the fuel, slight reduction in lubricating oil viscosity with usagewas observed but it was not significant enough to alter the lubricatingoil change interval. Agarwal investigated the effect of B20blend of linseed oil methyl ester on the tribological properties of lubricating oil in aendurance test [5].He reported that the fuel dilution was lower for the lubricating oil from the biodiesel fuelled engine in comparison to the diesel fuelled engine by measuring viscosity and flashpoint[5].Biodiesel is comparativelymore chemically reactive than mineral diesel due to presence ofoxygen in the molecular structure of biodiesel[6].Differencesin physical properties of biodiesel and mineral diesel cause differentlevels of fuel dilution of the lubricating oil. Hence, the effect ofbiodiesel on the lubricating oil degradation needs to be evaluatedinlong-duration engine tests before taking decision about theirlarge-scale usage.

vegetable oils to be used as the base stocks forlubricants because of their advantages suchas high biodegradability and high viscosity index. The wide spread interest in biodegradable lubricantshas resulted in comparisons of the chemical and physical properties of leading base stock candidates suchas vegetable oils, synthetic esters, and petroleum oils.When used as the base stock for lubricants, vegetable oils show weak oxidative stability. However, vegetable oil based lubricants can be used in some applications such as hydraulic fluids. Adamczewska and Wilson [7] developed lubricant formulations for farm tractors and hydraulic fluids using acombination of vegetable oils and additives. They reported that vegetable oil based lubricants showed lesswear in the pump test compared to mineral oils. A use of vegetable oils under a mild condition was also conducted by Adhvaryu et al. [8]. However, a variation of testing conditions was not performed in thisstudy. A study by Weller et al. [9] showed factors affecting wear and friction in both synthetic and naturaloils are speed, time, temperature, and additive dosage. This study should be extended to cover variety ofvegetable oils.

In this study the effect of B40 and diesel on the degradation of lubricating oil was experimentally investigated during a single life cycle (we have selected 2000 km for our present study)of lubricating oil. Various tribological studies on lubricating oil samples, drawn in a service interval for the single cylinder engine were conducted, in order to correlate the comparative performance of the two fuels (diesel and B40%) and the effect of fuel on lubricating oil performance were conducted to correlate the effect of fuel properties on lubricant degradation and wear study properties.

2 Material and Method

Experiment is conducted with the lubricating oil of having a standard of SAE 20 -W40 in a four stroke single cylinder compression ignition engine[CI] and the properties of lubricating oil and the specification of engine was shown in Table 1 and Table 2 and properties of wear study in Table 3.

Table 1:Properties of lubricating oil

Property	Pure lubricating oil	Mineral Diesel lubricating oil	Cardanol B40l lubricating oil
Density(g/cc)	1.117	0.950	0.992
Viscosity(cSt)	15.76	13.03	28.78
Viscosity index	920	792	886

Flash Point(°c)	183	158	146
Ash content(%)	0.45	0.49	0.55
Moisture Content(%)	0.13	0.14	6.1
TBN(mgKOH/g)	43	12	27
TAN(mgKOH/g)	0.54	0.26	0.63
Acid Value	1.02	1.99	5.87
Volatile Matter(%)	0.08	0.05	0.18

Recommended oil change interval duration for the engine is 2000 km and the test is conducted in the same period, fueled with diesel and B40 respectively. In the first phase engine as operated by a crude petroleum diesel fuel at a distance covering the specified service interval of 2000 km and in second phase cardanol B40 oil was used as fuel.The vehicle was operated in the daily routine road with varying traffic conditions.For comparing the effect ofchanges in lubricating oil, samples were drawn from the oil sump and various number of tests were conducted on the lubricating oil samples in order to evaluate the properties of lubricating oil such as measurement of density, viscosity, viscosity index, flash point, Ash content, Moisture content, Total base number(TBN).Total acid number(TAN), Acid value and volatile matteretc and the tests were conducted as per the standards of America Society for Testing Materials (ASTM).

The density of the lubricating oil samples was measured density meter (ASTM D1298). Viscosity of the lubricating oil samples was determined at 40^0Ctemperature using kinematic viscometer(ASTM D445). Flashpoint lubricating oil was measured by the (ASTM D92**)** method, Total base number and Total acid number was measured by ASTM D664.

Table 2:Technical specifications of the test engine

Mark & Model	**Royal Enfield Diesel Bullet 1986**
Engine Type	Air cooled
Engine Displacement	325.00 cc
Number Of Cylinder	1
Valves Per Cylinder	2
Number Of Strokes Per Cycle	4
Transmission Type	Manual
Number Of Speed Gears	4
Max Torque	15.00 Nm @ 2500 RPM
Bore/Stroke	78.0/68.00 mm
Fuel Capacity	13.0 litter

2.1 Wear Experiment Procedure

Wear is a process of removal of material from one or both of two solid surfaces in solid state contact. As the wear is a surface removal phenomenon and occurs mostly at outer surfaces, it is more appropriate and economical to make surface modification of existing alloys than using the wear resistant alloys

The experiment has been performed on a group of specimens for duration of 5 minutes, and load of 2 Kg, with speed 600 rpm. The set up is connected to a Data Acquisition System which computes friction force and coefficient of friction of said material. By fixing any two parameters with one variable parameter experiment is performed. Graphical representation of wear rate along with friction force and coefficient of friction is given by WINDUCOM software and the results will show the coefficient of friction in relation with (time, speed and load) and the systematic comparisons of one material with the other. Friction is a force that resists sliding and is measured by a coefficient which is generally considered to be constant and specific to various material.The setup of the method comprises of a pin with spherical surface as the tip and a circular rotating disk which is placed at a perpendicular with respect to the spherical pin surface. The diameter of the pin is 10mm and the length is 30mm.The disk is made of hardened steel on which the pin is held with a jaw in the apparatus and rotation is provided to disk which causes wear of the pin on a fixed path on disk. The pin is pressed against the surface of the disk with load being applied with the arm attachment provided to the apparatus. Machine is attached with a data acquisition system and WINDUCOM 2010 software which gives result values and graphs.

Table 3 :Specifications Pin on disk wear machine

Test parameters	Values
Specimens	Pin size:- 10 &12 mm diameter 32 mm long Ball : spherical ball ¢10
Wear Disc Size	Diameter 165mm, 8mm thick
Wear Track Diameter	Min:50mm,Max:500
Disc Rotation	Min:200rpm,Max:2000rpm
Normal Load	Min:5N,Max:200N
Friction Force	Min:0N,Max:200N
Wear Rate	Min: 0µm Max: 2000 µm

3 Result and Discussion

Properties of lubricating oil, runs with both diesel and biodiesel was studied as per the ASTM standards and were discussed as follows.

3.1 Density

Density measurement is important since they provide information on the addition of metals due to the movement of sliding particles over one another along with fuel dilution in lubricating oil. The density of lubricating oil samples from biodiesel and diesel operated engine were measured, and were plotted in the graph. Lubricating oil of Cardanol B40 fuelled engine shows higher rate ofchange of density in comparison to lubricating oil from mineraldiesel fuelled engine in entire duration of the test. Fuel dilutiondecreases the density of lubricating oil because the density of fuelsis lower than lubricating oil. Density of pure lubricating oil, Cardanol B40 and mineral diesel was 1.117,0.992 and 0.950 (g/cc) respectively therefore fuel dilution of lubricating oil by Cardanol B40 causes lesser reduction in density of lubricating oil in comparison to mineral diesel.However, the most important observation of thisstudy was that biodiesel-fuelled engine oil had lesser deterioration in density throughout the entire range of engine operation.

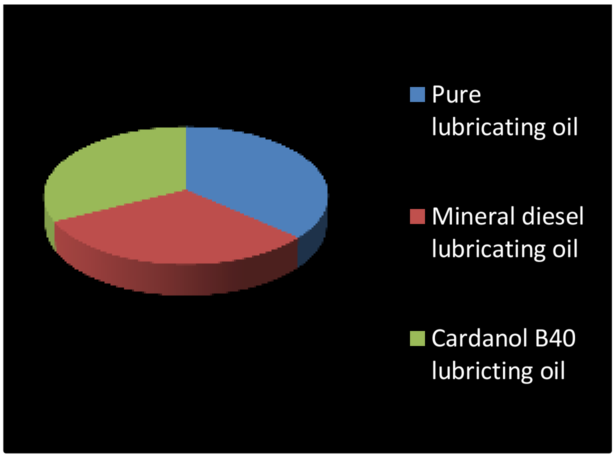


Fig:1 Lubricating Oil Density

3.2 Viscosity

Fig. 2 shows the variation of viscosity of lubricating oil samples of pure lubricating oil, mineral diesel and cardanol B40 fuelled engine measured at 40°C temperature. Viscosity of lubricating oil samples drawn from both engines initially increases sharply. Then rate of increase in viscosity for fuelled B40 lubricating oil becomes higher than that of mineral diesel. Lubricating oils viscosity starts decreasing after 2000 km for both fuels. Lubricating oil of Cardanol B40 fuelled engine shows higher reduction beyond 2000 km..Oxidation and polymerization of lubricating oil tend to increase the viscosity, whereas fuel dilution tends to decrease the viscosity. This trend of viscosity indicates that there is higher degree of fuel dilution in case of Cardanol B40, which is causing higher rate of viscosity increase in the beginning due to fuel induced oxidation.

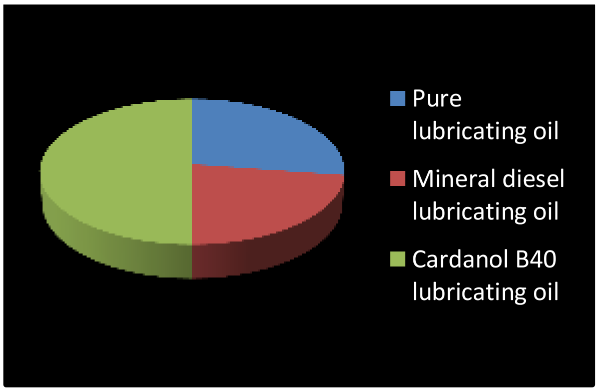


Fig:2 Viscosity of lubricating oil

3.3 Viscosity Index

The VI indicates changes in viscosity with changes in temperature, The high VI indicates small change in temperature, whereas a low VI indicates high changes in temperature, The viscosity of liquid decreases as temperature increases .The viscosity of a lubricant is closely related to its ability to reduce friction.viscosity index of Cardanol B40 fuelled engine have higher VI than mineral diesel lubricant oils ,which ensures that lubricants remain effective even at high temperatures by maintaining the thickness of the oil film. Hence lubricants are suitable for a wide temperature range.

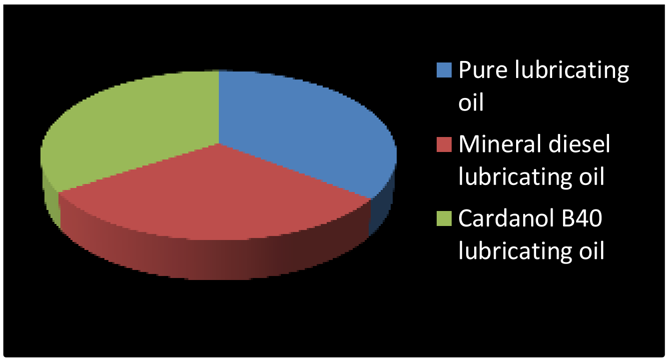


Fig3 Viscosity Index

3.4 Flash Point

Flash point of lubricating oil samples reduced with usage for both fuel both fuels (Fig.3). Flash point of pure lubricating oil, Cardanol B40 biodiesel and mineral diesel used in this study were 183.146 and 158^{0}C respectively. Same levelof fuel dilution for CardanolB40 would have resulted in lower flashpoint depression of the lubricating oil due to higher flash point temperature of Cardanol B40 compared to mineral diesel Almost similar flash point after 2000 km engine operation andviscosity variation indicated that fuel dilution of lubricating oil was higher for Cardanol B40 fuelled engine even though depression in lubricant'sflash point was lower for cardanol B40 compared to mineral dieselFlash point.

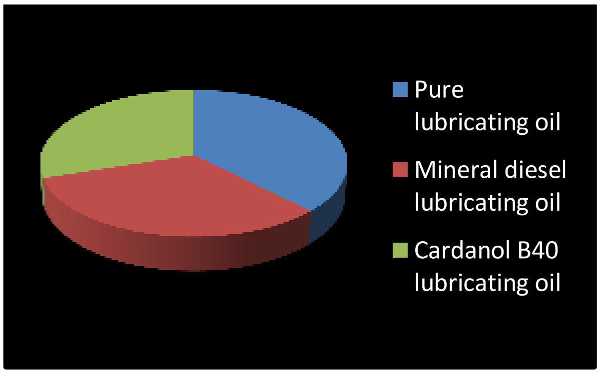


Fig:4 Variation of Flash Point of The Lubricating Oil Sample

3.5 Ash Content

Ash content reflects non-carbonaceous material in the lubricating oil and it mainly indicates metallicwear debris and abrasive foreign particles like sand entering thesystem. Since both of the systems were operated underidentical conditionsthe contribution of foreign particles may besafely assumed to be similarAshcontent of the lubricating oil samples drawn from pure lubricating oil, mineral diesel and Cardanol B40 fuelled engines is presented in fig 4.Their is slightly increase in ash content of lubricating oil of Cardanol B40 fuelled engine compared to mineral diesel fuelled engine suggests that Cardanol B40 fuelled engine produces possibly higherwear debris.

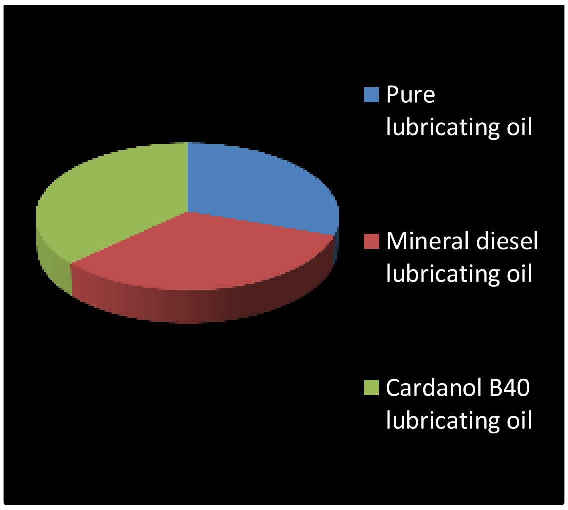


Fig:5 Ash Content of lubricating oil

3.6 Moisture Content

Moisture content was determined using ASTM D 1744procedure. Water in the lube oil samples was determined byKarl Fischer titration method. Traces of moisture are intolerableas water contamination in engine oil can cause increasedcorrosiveness inside engine. Water also causes additive dropout therefore precipitation of additives from the oil. Water in the lubeoil may also indicate excessive fuel dilution, glycol leakage, and short trip driving. Mettler DL18 Karl Fischer titrator was used for determination of moisture content. Lower moisture content is observed in the lubricating oil from biodiesel-fuelled systemItcan also be seen that initial rate of absorption of moisture was quite high, Lower amount of absorption of moisture by the lubricant from cardanol B40-fuelledsystem may also be an indirect consequence of additionallubricating property exhibited by cardanol B40.

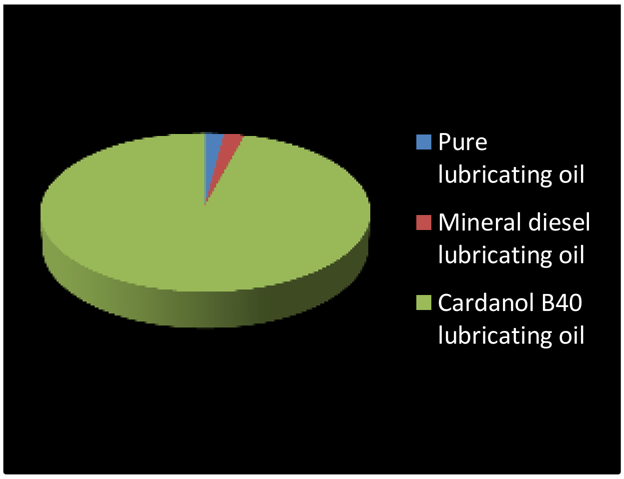


Fig:6Moisture content of lubricating oil

3.7 **Total Base Number**(TBN)

The total base number is the amount of alkaline additives present in lubricant, Engine oils are formulated with alkaline additives in order to combat the build-up of acids in a lubricant as it breaks down and that are capable of neutralizing the acid product of combustion. The TBN value decrease when the oil loses its capability of neutralizing.Oxidation of ester molecules of biodieselpresent in the lubricating oil encourage formation of organicacids, which reduce the reserve alkalinity of lubricating oil. The result shows the TBN value decreases according to running distance

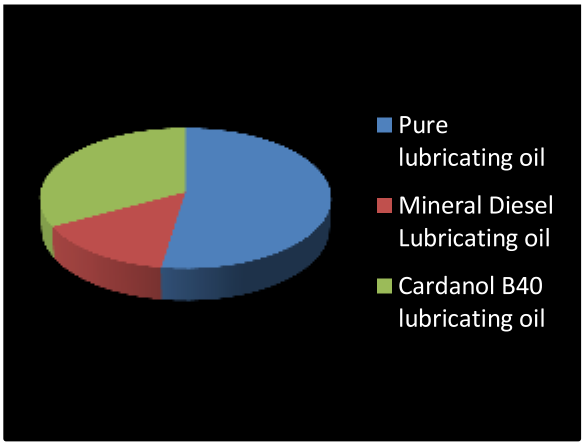


Fig:7Total Base Number of lubricating oil

3.8 Total Acid Number(TAN)

Total acid number is the total quantity of acid or acid like constituents in the lubricant oil A high concentration of acidic compounds in a lubricant can lead to corrosion of machine parts and clogged oil filters due to the formation of varnish and sludge. When a lubricant breaks down, acidic by-products will be formed from the chemical decomposition of the base stock and additives in the presence of air and heat..High TAN value indicate that lubricating oil involved in chemical reaction or react with metal.TAN indicates the usefulness of the oil. Result shows there is increase in TAN value and there is oxidation and contamination.

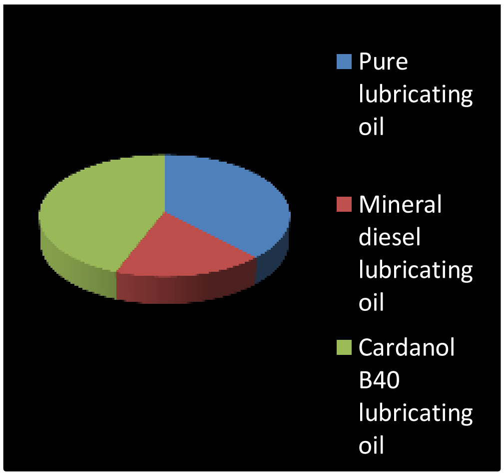


Fig:8 Total Acid Number of Lubricating Oil

3.9 Acid Value

The acid value is a property provides the measure of acidic substance in the lubricating oil and is expressed in KOH/g of a sample used to monitor the degradation of oil Acids are formed as oil oxides with age and service. It indicates that there is increase in the acid value of Cardanol B40 fuelled engineHigh acid levels can indicate excessive oil oxidation or depletion of the oil additives and can lead to corrosion of the internal components.

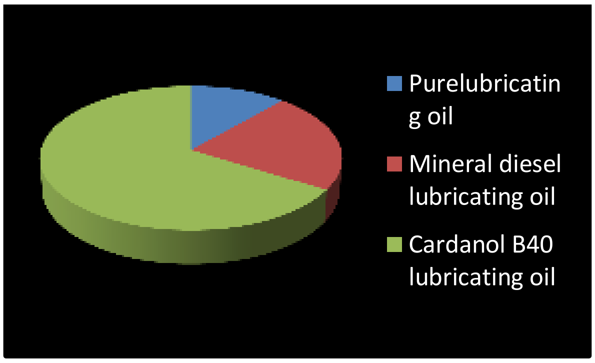


Fig:9Acid Value of lubricating oil

3.10 Volatile Matter

Volatile matter is determined as the loss in mass, less that due to moistureThis determination is to be carried out to correct the loss of base oil, when lubricating oil samples generate such loss, Cardanol B40 has a low volatile matter percentage while comparing with pure lubricating oil and diesel lubricating oil. Due to fuel dilution in lubricating oil

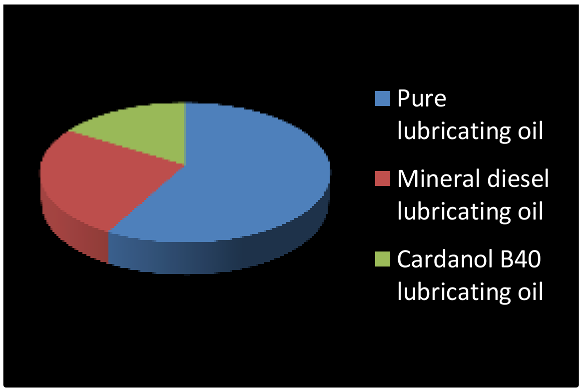


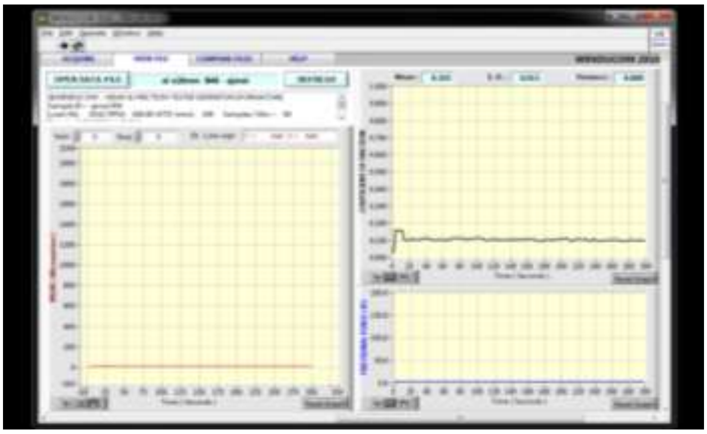
Fig:10 Volatile matters in lubricating oil

3.12WEAR RESULT AND DISCUSSION

Materials	Friction Force(N)	Wear(µm)	Coefficient of Friction
B40 FUEL	3.00	6.86	0.1008
20W-40	1.32	94.00	0.1012
Mineral Diesel lubricating oil	2.86	11.49	0.1425
Cardanol B40 lubricating oil	2.64	16.34	0.0432

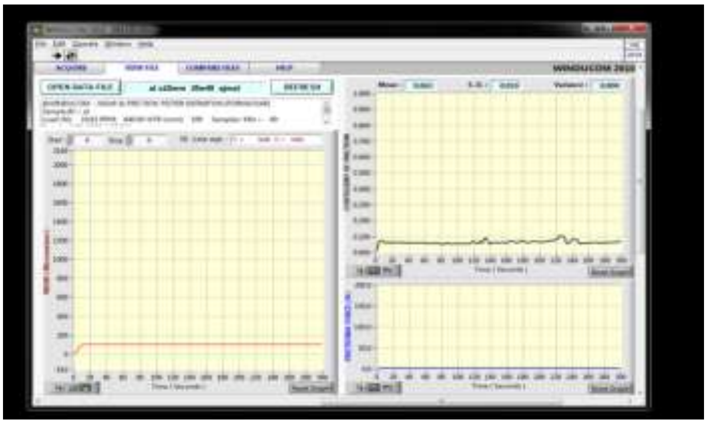
3.14 Graphical Representation of Wear

3.14.1 Test Result For B40 Fuel



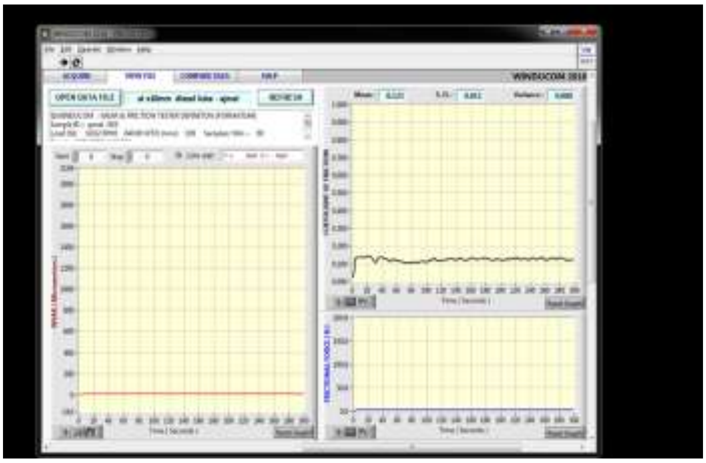
Graph 1.1 wear, coefficient of friction, frictional force of B40

3.13.2 Test Result For 20w-40 Lubricating Oil



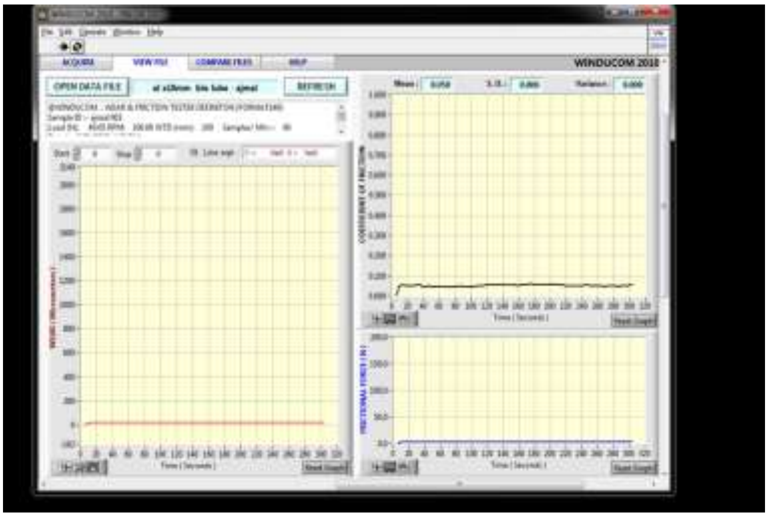
Graph 1.2 wear, coefficient of friction, frictional force of 20W-40 Lube oil

3.14.3 Test Result For Mineral Diesel Lubricating Oil



Graph 1.3 wear, coefficient of friction, frictional force of Mineral Diesel lubricating oil

3.14.4 Cardanol B40 Lubricating Oil



Graph 1.4 wear, coefficient of friction, frictional force of Cardanol B40 Lubricating Oil

4. Conclusions

Effect of 40% cardanol biodiesel blend on lubricating oil tribology was studied and compared to mineral diesel in a 200 h long road test Important conclusions from this study are as follows

- Variation in viscosity of lubricating oils from biodiesel and mineraldiesel fuelled engines indicated possibility of higher oxidationand polymerization of lubricating oil drawn from biodieselfuelled engine.
- Higher increase in density and ash contentwasobserved for biodiesel fuelled engine's lubricating oil with usage.
- CardanolB40 would have resulted in lower flash pointdepression of the lubricating oil due to higher flash point temperature of Cardanol B40 compared to mineral diesel.
- High ash content of the lubricating oil from biodiesel fuelledengine indicated possibility of higher wear trace metals, whichwere confirmed by measurement of wear trace metals in lubricating oil samples.
- TBN value increased it leads to degradation and cause corrosion to components.
- From all the first four graphs of oil we understand the fact that the wear rate is comparatively higher.
- Cardanol B40 lubricating oil has wear 16.34 micrometer and friction force 2.64while coefficient of a friction is 0.0432.
- From the above experiment wear resistance of 20W-40 is maximum with intermediate frictional force and coefficient of friction.
- Graph of a cardanol B40 for wear rate is smooth curve in nature.
- Cardanol B40 and Mineral diesel lubricating oil shows different wear rate.

No operational problem was observed during 2000 km road running test of cardanol B40fuelled engine in comparison to mineraldiesel fuelled engine except higher oxidation of lubricating oil of Cardanol B40 fuelled engine, which indicated the need for reformulationof lubricating oil for biodiesel fuelled engines, in case of large-scale implementation.

References

1. Atul Dhar, Avinash Kumar Agarwal, "Experimental investigations of effect of Karanja biodiesel on tribological properties of lubricating oil in a compression ignition engine" Elsevier paper,13April 2014.
2. "Lubricating Oil Tribology of a Biodiesel-Fuelled Compression Ignition Engine" by: Avinash Kumar Agarwal, IIT Kanpur, India 2003 Fall Technical Conference, ASME Internal Combustion Engine Division and Rail Transportation Division, Erie, Pennsylvania, USA, September 7-10, 2003.
3. Tom Krawczyk, "Biodiesel:alternative fuel makes inroads buthurdles remain", Inform, No.8, Vol. 7, pp. 801-814, 1996.

4. Verhaeven E, Pelkmans L, Govaerts L, LamersR,Theunissen F.Results of demonstration and evaluation projects of biodiesel from rapeseed and used frying oil on light and heavy duty vehicles. SAE Paper 2005. 2005-01-2201
5. Lin et al. comparison of PAH and regulate harmful matter emission from biodiesel blends and paraffinic fuel blends on engine accumulated mileage test fuel[2006:85:2516:23]
6. Staat F, Gateau P. The effects of rapeseed oil methyl ester on diesel engineperformance exhaust emissions and long-term behaviour – a summary of threeyears of experimentation. SAE Paper 1995:950053.
7. Adamczewska JZ, Wilson D. Development of ecologically responsive lubricants, Journal of synthetic lubricants1997;**14**:129-142
8. Adhvaryu A, Erhan SZ, Perez JM. Tribological studies of thermally and chemically modified vegetable oils for use as environmentally friendly lubricants, Wear2004;**257**:359-367.
9. Weller DE. Study of the effect of chemical structure of esters and vegetable oils on friction and wear with and without wear additive, *PhD.* Thesis, The Pennsylvania State University, 1999.

*****